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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Summer and Winter Grades of Lubricants

Gear Cutting at High Speeds

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Summer and Winter Grades of Lubricants

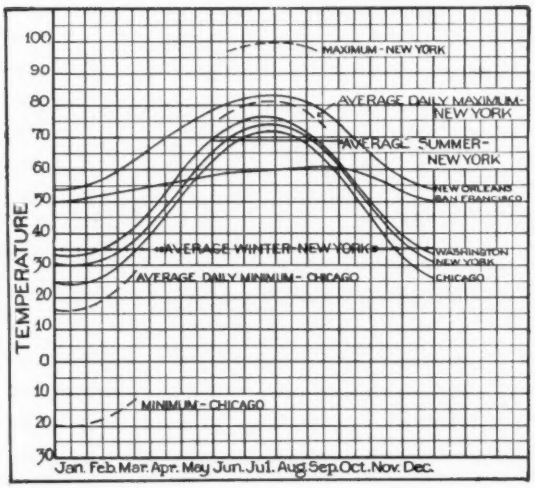
Their Application to Electric Street Railways

DURING the thirty-three years following the official opening of the first electric railway at Richmond, Va., in 1888, the improvements in electric street railway equipment and operation have been many and have resulted in the present highly efficient cars operating in our cities and in interurban service. While this development of equipment has gone on, unfortunately the improvement in lubricants has not until very recently kept pace, and even today many railways are still using the same lubricants originally developed for the first street cars.

One of the greatest of recent improvements in lubrication is the use of different grades of lubricants for summer and for winter. The rolling stock equipment of electric street railways is exposed to atmospheric temperatures in different localities of the country and these varying temperatures should be considered in specifying lubricants to be used on such equipment. Those directly responsible for efficient lubrication and the uses of oil in general, are aware of the fact that lubricating oils get thick and sluggish in cold weather. This characteristic of oils, regardless of what base crude or by whom manufactured, is one which must be given proper consideration both by the manufacturer and by the users of lubricants. An idea of how oils are affected by temperature changes is shown in the temperature viscosity curves of various oils in the chart published in the June issue of "Lubrication".

The efficient lubrication of any kind of a bearing surface can be accomplished satisfactorily only when the lubricant is fed regularly. The constant supply of lubricant is influenced, primarily, by the fluidity of the oil at the operating temperature. Since fluidity, which is usually expressed in terms of viscosity, is dependent upon temperature, the operating temperature is the determining factor in selecting suitable grades of lubricants for summer and winter service.

Chart No. 1 shows the average temperature throughout the year for a period covering the past thirty-five years at five of the principal cities in the United States. These figures are furnished by the United States Weather Bureau at New York. Attention is called to the very uniform temperature in the city of San Francisco throughout the entire year. Evidently summer and winter grades of lubricants do not have to be considered in the latter mentioned city to secure desired results.



Furnished by U. S. Weather Bureau

Chart 1

AVERAGE ATMOSPHERIC TEMPERATURE THROUGHOUT THE YEAR IN VARIOUS CITIES

During the months of June, July, August and September, the average temperature at New York City is 69° F., whereas during the months of December, January, February and March the average temperature is 35° F. Washington, D. C., is about 3° hotter in summer than New York, and Chicago is about 6° F. colder in the winter. In New York City, about the first of August, the average daily maximum temperature is 81° F. and at intermittent intervals it sometimes reaches 100° F., so that when selecting an oil for an average temperature of 69° F., we must at the same time allow a margin of safety sufficient to take care of temperature conditions at 100° F.

At the lower end of the temperature scale, we find Chicago with an average daily minimum temperature of 16° F. during the month of January and a minimum temperature for short intervals of as low as 20° below zero. Oils for the latter service should be sufficiently fluid to feed to the bearings at this temperature.

Obviously in the winter months the oil should be sufficiently low in viscosity to feed to the bearing surfaces in proper quantity, and in the summer months it should be heavy enough in viscosity to prevent too rapid draining from the bearings, and to maintain a sufficient film at the higher temperature to afford efficient lubrication. The ideal condition would be to have the oil at its average summer operating temperature of the same viscosity as at its average winter operating temperature. Such a condition is, of course, a physical impossibility when one oil is used, but when two oils are used, their viscosities and other physical characteristics can be selected to meet these conditions in the proper manner.

For equipment which is operated continually out of doors, such as electric street railway equipment, where atmospheric temperature has a direct influence on bearing temperatures, the viscosity of the summer grade for the vicinity of New York City should be the same at 69° F. as the winter grade at 35° F.

Practical experience has proven that under the severest sort of service, a straight mineral oil of 100-105 seconds Saybolt viscosity at 210° F., gives the most satisfactory service in motor armature bearings, axle bearings and journal bearings for summer use. An oil thinner than this will not have a sufficient factor of safety to take care of the high temperatures which frequently occur. Any higher viscosity lubricant is unnecessary, and as the frictional temperature of the bearings increases with the increased viscosity of the oil, the viscosity required for extreme temperature conditions should not be exceeded.

Chart No. 2 shows the operating temperatures of four bearings, A, B, C, and D, corresponding to various atmospheric temperatures. Bearing B, under average summer temperatures, runs at 143° F. At this temperature the

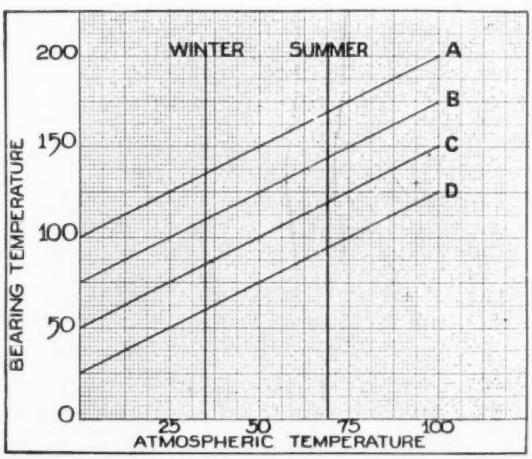


Chart 2

APPROXIMATE VARIATION OF BEARING TEMPERATURES WITH ATMOSPHERIC TEMPERATURE

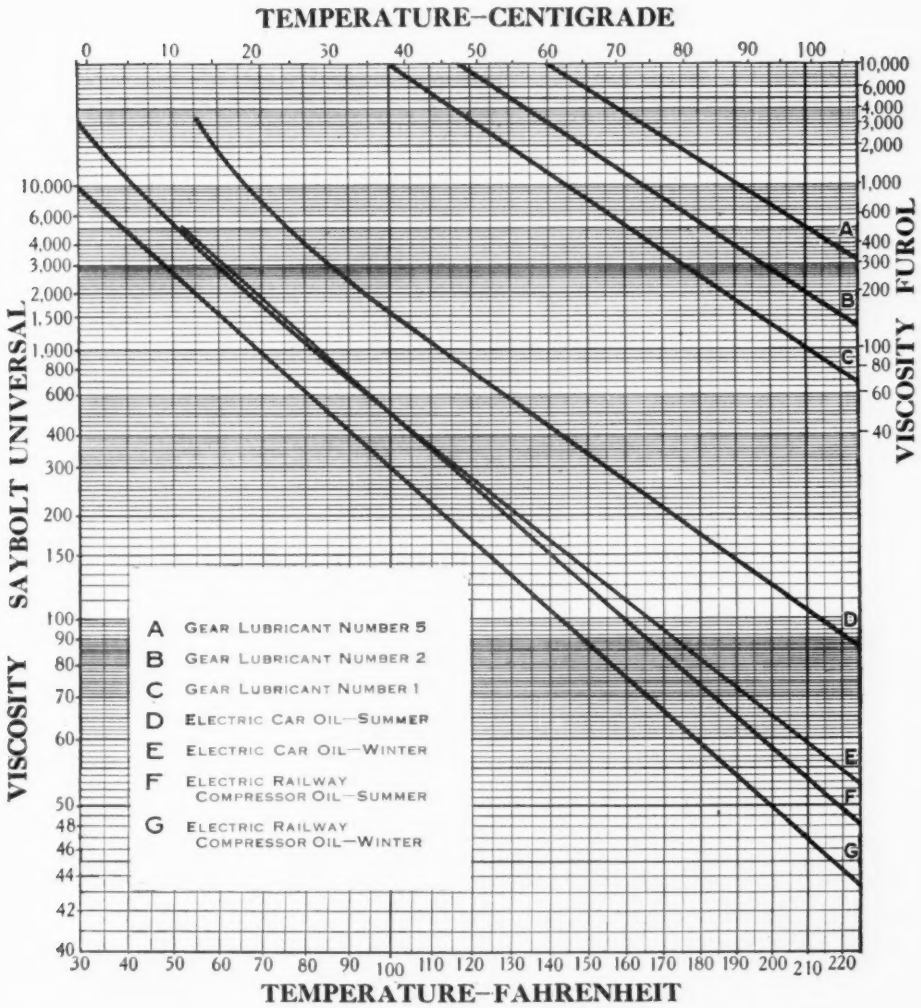

TEMPERATURE–CENTIGRADE
0 10 20 30 40 50 60 70 80 90 100
VISCOSITY SAYBOLT UNIVERSAL
10,000 6,000 4,000 3,000 2,000 1,500 1,000 800 600 400 300 200 150 100 90 80 70 60 50 48 46 44 42 40
VISCOSITY FUROL
10,000 6,000 4,000 3,000 2,000 1,000 600 400 300 200 100 80 60 40
A GEAR LUBRICANT NUMBER 5
B GEAR LUBRICANT NUMBER 2
C GEAR LUBRICANT NUMBER 1
D ELECTRIC CAR OIL—SUMMER
E ELECTRIC CAR OIL—WINTER
F ELECTRIC RAILWAY COMPRESSOR OIL—SUMMER
G ELECTRIC RAILWAY COMPRESSOR OIL—WINTER
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
TEMPERATURE–FAHRENHEIT

Chart 3

THE VISCOSITIES OF VARIOUS LUBRICANTS RECOMMENDED FOR ELECTRIC STREET RAILWAYS AT DIFFERENT TEMPERATURES

summer grade of oil referred to above has a Saybolt viscosity of 390 seconds. If the same bearing were cooled down to 109° F., the average winter working temperature, the summer grade of oil would be entirely too viscous. At the latter temperature the viscosity of the winter grade should also be approximately 390 seconds Saybolt. Referring to the curve, it will be noted that the winter grade of electric car oil is slightly lighter than this viscosity at the normal winter operating temperature.

It is usually desirable to make the winter grade of car oil slightly lighter than the corresponding viscosity of the summer grade, as explained above, so that it will feed properly under the very low temperatures of severe or, rather, abnormal weather.

Considering the lubrication of electric railway air compressors, we find from experience that two grades of lubricants are also necessary.

The usual practice in the past has been to use the same viscosity compressor oil the year round, and in making the oil of sufficiently low pour test for winter use, it was necessary to use an oil of such low viscosity as to make it unsuitable for efficient lubrication during the summer months. While the lubricating requirements of an air compressor are quite different from those of bearings and gears, they are to a certain degree influenced by temperature varia-

tions, combined with the effects of the heat of compression, and it is essential that the same consideration be given to viscosity in this case as is demanded in other classes of lubrication.

A grade for winter use with a viscosity of 300 seconds Saybolt at 100° F., will provide a satisfactory seal for the piston rings and maintain the functioning of the compressor at its proper efficiency. Since the compressor draws air from the inside of the car, which is heated in the winter, and is somewhat warmer than the outside air, and as the car is usually cooler than the street temperature in the summer, the range of difference in the viscosity of the summer and winter grades need not be as great as in the case of the car oil.

The effect of summer temperatures is great enough to make it necessary to use an oil of at least 500 seconds Saybolt at 100° F., and when such an oil is used, there will be an improved piston seal, thereby increasing the compressor efficiency and, at the same time, greatly reducing the oil consumption during summer months. This improvement over the use of one grade of compressor oil throughout the year, is an important factor in electric street railway air compressor performance.

Gears also are exposed to the extremes of temperatures. The summer and winter grades should therefore have a viscosity variation corresponding directly to the average temperature difference. Gear lubricants are of necessity more viscous than the other lubricants referred to, so that it is practically impossible to measure their viscosities at the operating temperatures. Consequently all viscosities of gear lubricants are taken at 210° F. and calculated from curves for other temperatures. On the basis of 5,000 seconds Saybolt at 210° F. for the summer grade, and 1,000 seconds Saybolt at 210° F. for the winter grade, these respective gear lubricants will have exactly the same viscosities at the average temperatures for summer and winter weather. Of course, where average winter temperatures are higher than the average of New York, the viscosity of the winter gear lubricant can be raised to 2,000 seconds Saybolt at 210° F., if desired.

For equipment so directly affected by atmospheric temperature conditions as electric street railway cars, it is absolutely essential that careful attention be given to the use of the proper grades of lubricants for summer and winter use. The use of lubricants of the correct viscosity will result in minimum power consumption through decreased frictional losses and increased life of bearings and all parts affected by frictional wear.

To get these benefits it is essential that the grades be changed at the proper time of the year, so that winter grades will not be used too late in the spring and summer grades too late in the fall.

From the temperature chart it will be seen that the temperature half way between average summer and winter, occurs during the last week in April and the last week in October. Evidently the change in grades should be made about this time, but instead of waiting until the exact date arrives, to make an abrupt change, it should be started at least ten days or two weeks before a general normal change of temperature is expected. In the spring, it will be found that compressors, gear cases and waste are full of winter lubricants which will continue to have an influence upon lubrication until they are entirely eliminated from use. The same condition exists with summer lubricants in the fall. On this account it is advisable to start the gradual use of the summer grade on inspection periods, commencing about April 15th and the winter grade about October 15th. The increasing percentage of the summer oil applied will raise the viscosity of the oil already on the equipment slowly and quite in accordance with actual temperature changes. In this way any unseasonably cool or warm days will be taken care of automatically and in a proper manner.

Conditions vary in different parts of the country and it is always necessary to use judgment as to the exact date selected to change lubricants to meet conditions, and as it would be extremely wasteful and, in some instances, quite impossible to consider cleaning all oil receptacles at any given period, due allowance should be made as to seasonal conditions, so that this waste can be avoided by gradually increasing or reducing the viscosities of the oils as normal temperature conditions demand.

Gear Cutting at High Speeds

Investigation of Controlling Factors

IN THIS article is described an investigation made with the assistance of the Brown Lipe Gear Co. on cutting alloy steel automobile gears at high rates of production, which was undertaken as one means of studying the relative values of different cutting oils. High production rates are impossible without some type of cutting oil and it seems logical therefore to believe that some classes of cutting oils are more effective for high production than others. The principal interest in these experiments centered about roughing cuts, where the sole object is the removal of metal at the fastest economical rate. The means by which this rate can be determined quantitatively are not generally understood in spite of its commercial value, and it is accordingly believed that production men will be interested in the methods used, and type of result secured.

Those who have not been able to study modern methods of manufacturing such gears as were cut in these experiments, will probably be interested in a short discussion on the fundamental methods used, before the details of the experiment are given.

Principles of Gear Cutting

Modern gears are almost universally made on the so-called involute system, and will run perfectly in mesh with a straight "rack" of the corresponding tooth size, the sides of the rack teeth being straight. This is a matter of great practical importance because of the simplicity of producing such teeth accurately. Even when

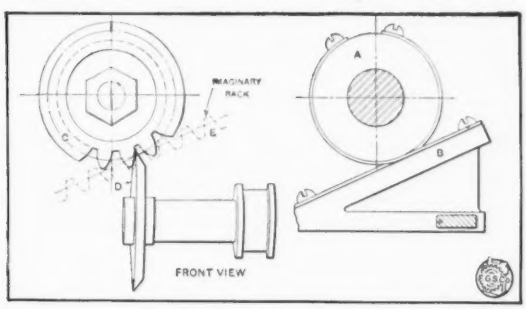


Fig. 1
Diagram showing principle of the involute—Cutter and Grinder

the cutters of this system, as will be described presently, are pinion-like cutters as shown in figure 5, instead of racks, they can be ground to a true involute form by rolling in contact with a straight sided grinding wheel as shown in figure 1. In this diagram, the cylinder A represents the rolling or "base circle" of the cutter. This cylinder rolls on the flat surface B and is constrained from slipping by the action of the steel tapes which positively control its rolling motion. The cutter C is secured to the cylinder A and will roll up and down the surface B as if in mesh with the imaginary rack E shown by dotted lines. Since, as mentioned before, the rack has straight sided teeth, a flat faced grinding wheel D will act like one face of a rack tooth, and when the cutter is rolled against it, will grind or "generate" a true involute surface on the cutter tooth.

Modern gear production is founded almost entirely on the generating method. Fundamentally it is well illustrated by the homely example of assuming a gear blank of soft plastic material rolled in contact with a rack so that teeth will be molded in it, as in figure 2, though

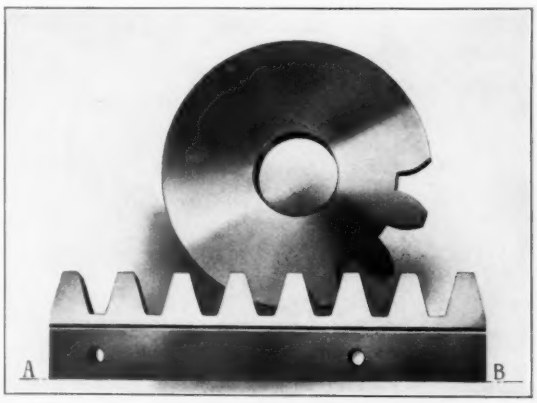


Fig. 2
Principle of "Generating" a Gear from a Rack

of course, some precaution must be taken to prevent slipping. All gears so made of any diameter would be interchangeable and run together correctly. Gears of steel would be generated in the same way, by reciprocating the rack parallel to the gear axis, while the gear is rolling, provided the edges of the teeth of the rack were sharp and suitable for cutting, like a planner. This method would require the use

of a rack at least as long as the circumference of the largest gear cut, and as this is naturally impractical, three modifications have been created for commercial gear cutting, which are as follows:

1. A rack of but few teeth is used, which is disengaged from the gear it cuts after cutting one or sometimes more teeth, and is then returned the distance it had traveled for that cut, and starts a new cut. This system is made use of in the Maag Gear Shaper which is shown in figure 3, while cutting a 92-inch gear. The ram carrying the cutter has a vertical reciprocating motion. One of the actual cutters is shown in figure 2.

2. Instead of a rack cutter, a pinion-like cutter is used (with teeth formed by rolling with a rack) which rotates with the work, reciprocating all the while just as before. This is characteristic of The Fellows Gear Shaper used in these experiments. Diagrammatically the motions are shown in figure 4, where the ram carrying the cutter is reciprocated by a rack and pinion from the Cutter Drive Shaft. A close view of the cutter at work is given in figure 5 of the cutter and work while cutting internal gears in these experiments. This is the only type of gear cutter which can be used for generating internal gears.

3. If a rack were given a rotary motion about the axis A-B (figure 2) instead of a reciprocating motion, it would cut in the same way. This is the cutting principle of the hob, which may be thought of as a series of racks rotating about the same centre line but advancing as a helix, as shown diagrammatically in figure 6 in elemental form, where all change gears for making possible the cutting of various size gears at various cutting speeds and feeds, are omitted. A comparison

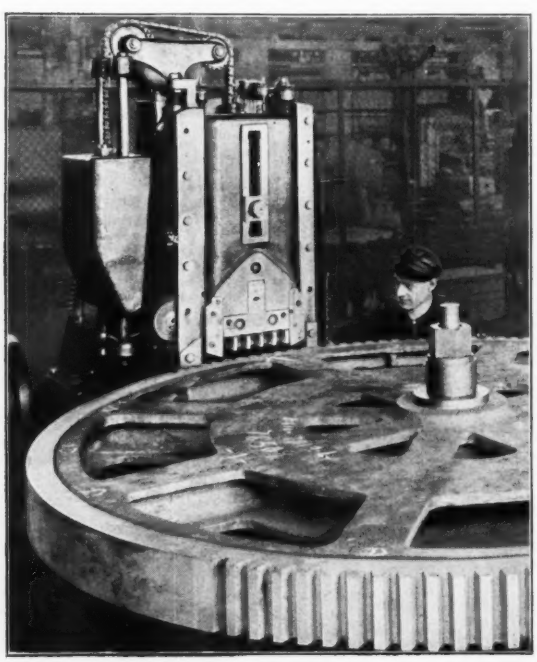


Fig. 3

A Maag Gear Shaper cutting a 92-inch 140-tooth Spur Gear, with a reciprocating rack cutter having but five teeth

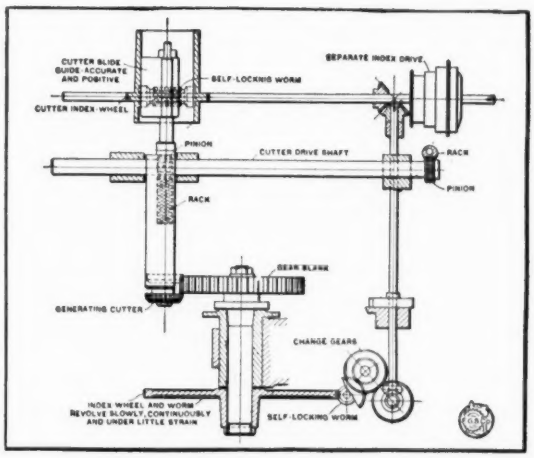


Fig. 4

Schematic diagram of the Fellows Gear Shaper

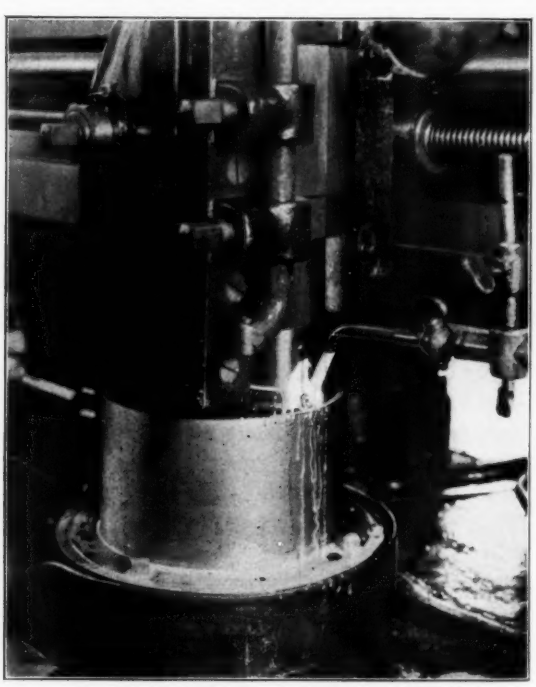


Fig. 5

A Fellows Gear Shaper cutting the internal teeth of a dry disc-clutch drum. Notice the characteristic pinion-like cutter, which has a rapid vertical motion a little greater than the length of the drum teeth, and rotates slowly with the drum until all the teeth are cut. A stream of Soluble Oil is shown flowing over the cutter.

of the nature of the cut when compared with the shaper system is shown in figure 7. A photograph of a hob is given in figure 9, which shows the individual "racks" staggered so that the teeth are really parts of an interrupted double helix wrapped about a cylinder at a suitable angle. In order to cut straight spur gears, the centre of the hob is inclined from a perpendicular to the gear

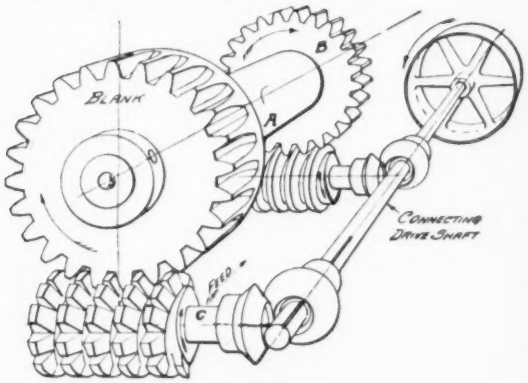


Fig. 6

An elemental schematic diagram of a gear hobber

centre line, as shown in figure 6. The worm and worm-wheel B, in conjunction with the bevels shown, cause the hob and gear blank to rotate at the proper relative speed, while the hob and its support are moved slowly parallel to the axis of the gear blank until the whole face of the blank has been cut. Figure 8 gives a "close-up" view of the Barber-Coleman Gear Hobbing Machine used in these tests, with the hob almost covered by

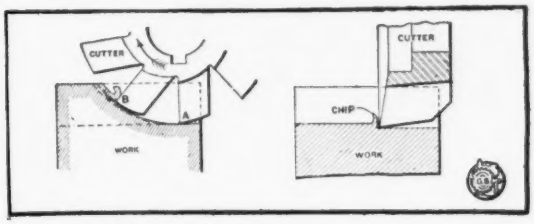


Fig. 7

A comparison of the types of cuts taken by a hob (left) and a shaper (right). The hob moves slowly to the left during a cut, removing metal while revolving. The shaper cuts by rapid strokes the full length of the tooth.

a stream of soluble* cutting oil. An interesting feature of the hobbing process of gear generation is that it makes use of continuous rotary motion of the cutting tool which makes possible the very high rates of removing metal characteristic of the hobbing process. It will be observed, however, that a hob is a much less simple form of cutting tool than the cutters of the shaping processes (see figures 2 and 5), and therefore much more difficult to manufacture accurately. It must

*"Soluble Oil" is a permanent milky white emulsion of water with an especially prepared mineral oil containing no animal oils.

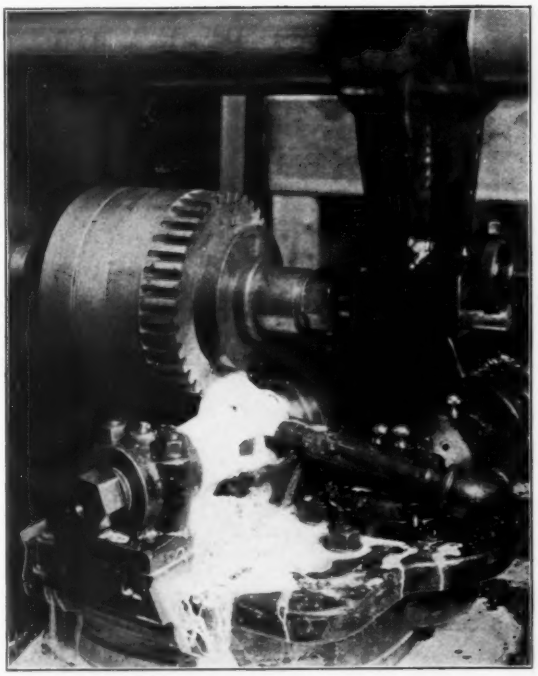


Fig. 8

A hob at work cutting a gang of four automobile transmission gears. The hob is almost hidden from sight by the stream of soluble oil. With its carriage, the hob moves slowly to the left until the remaining three gears are cut.

be remembered that the gears can be no more accurate than the cutting tools used.

As a matter of interest in passing, many manufacturing operations other than gear cutting are possible on these machines, such as flat cams cut on gear shapers, and splined shafts on a Hobbing Machine. Furthermore, all three types of machines can be used for cutting spiral gears. Additional mechanism must be added to the shaper type for this purpose, which is not necessary for the hobbing type.

Method of Test

In this brief description of methods of gear generating it has been attempted to clarify the details of the operations on which these cutting oil experiments were made. As stated before, interest in these experiments on gear hobbing was centered about roughing cuts only, and the finish was of little interest, so long as the smoothness was within reason. Under these circumstances the value of a cutting oil can be based on its ability to minimize the rate of wear or dulling of the cutting tools. So little information is available in regard to the quantitative measurement of the wear of cutting tools, when using various cutting oils, or how the wear develops on the type of tools used,

and its relation to various rates of cutting speed and feed, that much experimental work was necessary to determine these factors. The first experiments were all made with soluble oil and consisted of two series; the first was to determine the rate at which the wear of the cutting tool progresses during cutting at constant speed and feed; the second was to determine the effect of various combinations of speed and feed upon the extent of tool wear after a given quantity of metal had been cut, when using either a mineral oil with 40% lard oil, or a soluble oil.

Since the question of tool wear or dullness was of such importance it was necessary to determine some reliable method of measuring the actual extent of wear quantitatively. Considerable experimenting was required to determine the best way to do this. Finally it was found that the most satisfactory method was the direct measurement of the worn edges of the cutting tool by means of a small hand micrometer-microscope. There are two other ways by which the relative dullness of a tool might be determined also, (1) since more power is required to make a dull tool cut, and the increased power results (2) in the generation of more heat at the cut. It should accordingly be possible to secure an indication of the condition of the cutting tool by measuring the power consumption during a prolonged cut or by measuring the temperature rise of the cutting oil as it passes over the tool. All three methods of determining tool wear were tried in these experiments.

Test on a Gear Hobber

A Gear Hobbing machine with individual motor drive, was selected for these experiments because the power required for cutting was large in proportion to the power consumed by the friction of its bearings and parts. An Esterline recording watt-meter connected to the electric motor gave a graphic record of any change of cutting resistance during the test. This machine was used for rough-cutting the teeth of gangs of 3½% nickel steel automobile transmission gear blanks, having a tensile strength of 80,000 to 100,000 pounds per square inch. (S.A.E. 2320 of 25-35 scleroscope hardness.) This steel was purchased on specifications sufficiently rigid to assure reasonable uniformity of all the metal cut, a matter of much importance for such tests.

Hob Wear

The nature of the hob wear measured by the microscope is shown in Fig. 9. Each tooth is numbered, starting from the end towards the front of the machine when in use. These hobs are all double threaded, and the thread starting opposite the key-way is given a series of primed numbers. It will be noticed first of all that only a few of the teeth show signs of wear. A second point of interest is the curious nature of the wear, the sides and tips of the teeth being abraded as if from scraping against the metal, as shown more clearly in the enlarged view of tooth 15′ in figure 10, but the cutting edges are not rounded. In re-sharpening the hobs, metal is removed from the teeth by grinding away a radial strip lengthwise of the hob, until all the worn spots are removed.

Measurements were taken for each side and the center or tip of each tooth, of the maximum distance of the abraded areas from the leading edge, as shown by dimension "A" of figure 9 for the center and "B" for the "right-face" (when looking down on the cutting surface). This is a measure of the metal which must be ground off to remove all traces of wear at the point measured. From this data can be computed the number of gears which can be cut before a hob has been ground down by re-

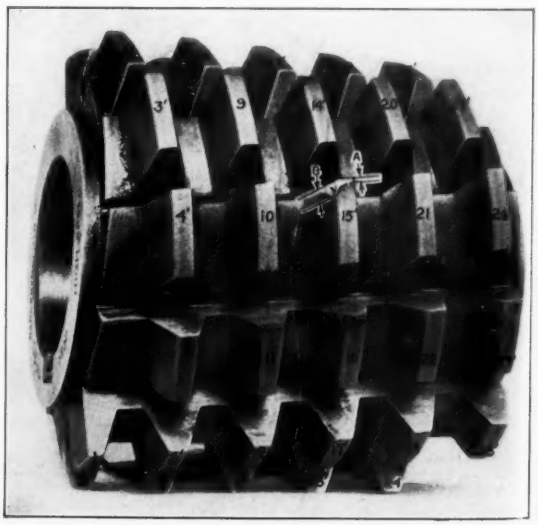


Fig. 9

A typical double threaded hob, with the teeth numbered to correspond with Fig. 11. An average was taken of the wear of corresponding teeth on the two "threads," for the data shown in all curves. Teeth 14′, 15′, and 16′ show typical signs of wear.

sharpening to the point where it is no longer of any use, and the proper share of its cost charged to each gear cut.

The first series of experiments was carried out with one part of soluble oil mixed with six parts of water, in which the hob wear was measured after each alternate "load" of gears was cut. It was necessary to remove the hob while making these measurements, but it was always replaced in exactly the same position. The gears cut during this test were 5-7 pitch* 1½ inch face, and having 38 teeth. A single "load"

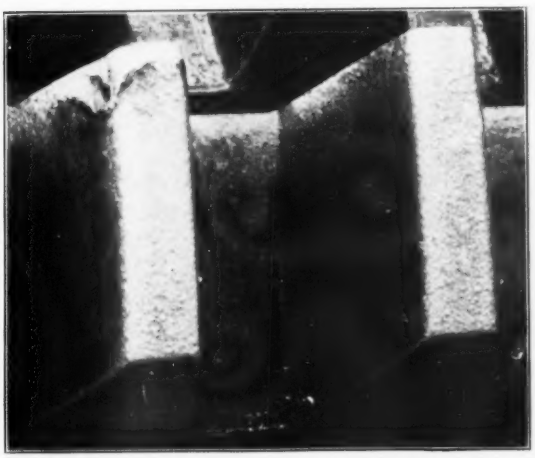


Fig. 10
An enlarged view of teeth 15' and 21 from Fig. 9 to show in greater detail the nature of tooth wear

consisted of six gears. In figure 11 is shown the wear recorded for the right face of each tooth after cutting various alternate loads of gears. It will be noticed that: (1) many teeth show no wear, (2) that the wear on each tooth increases regularly in proportion to the number of gears cut, and (3) that the number of the teeth showing wear gradually increases as teeth doing most of the cutting become dull. This latter has an important bearing on the number of gears which can be cut by a hob, because it is customary to "reset" a hob to a new position along its arbor, after it has become dull in one position, so as to get some use from the unworn teeth.

The connection between the extent of wear allowed to develop between re-grinds, the number of possible resets, and the hob cost per gear cut, is very important. The item of hob cost in cutting these gears is more than twice as

*This is a standard stub-tooth gear such as is almost universal in automobile work. It indicates that the diametrical pitch is 5, while the tooth length corresponds to that of the ordinary 7 pitch gear.

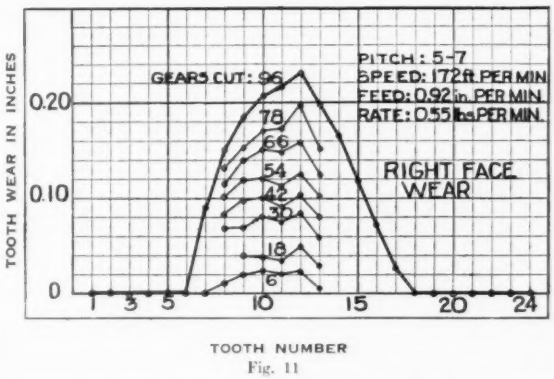


Fig. 11

great as the labor and overhead combined, and offers possibilities for reduction.

In figure 12 the data of figure 11 is shown in a different manner, in addition to the power data of this test. The recorded wear of all three parts of the individual teeth which showed the maximum wear in each instance, is indicated as it progresses with the number of gears cut. No indication is given of the sudden break-down point expected from the work of previous experimenters. The net power consumption curve was taken from the graphic records after deductions were made for bearing friction when the machine was running but not cutting. A noticeable increase is indicated

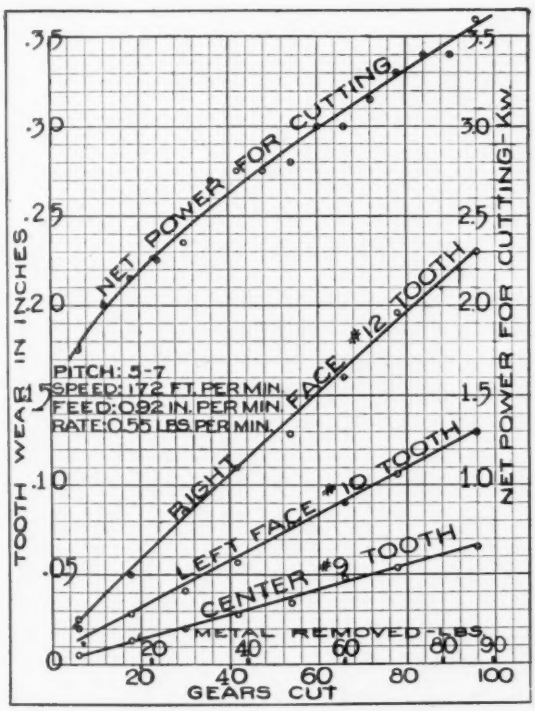


Fig. 12

in the power required for cutting, being over twice as great for the last gears cut as for the first gears.

Temperatures

In preliminary experiments an attempt was made to determine the quantity of heat liberated while cutting, by measuring the temperature of the oil stream just before striking the hob, and just after. For the latter reading a trough was arranged to collect the oil and direct it to the thermometer bulb before it had much chance to cool from exposure to the air. The results were disappointing because the oil stream was not of uniform temperature, and the presence of hot chips in various amounts made check readings out of the question. In the above series of tests from which the data of figure 12 was shown, the temperature recorded for the work and shown in figure 13 was obtained by laying a thermometer in the groove between two adjacent teeth the moment the cut was finished, with the bulb at the gear last cut, and surrounded by a piece of cotton waste until the thermometer reading ceased to rise. The results were not of great value because the large mass of metal making up a load of gears quickly cooled off the hottest parts. During many of the last cuts the gears being cut were over 212° F., as could be seen from the boiling of the soluble oil carried by them from the main stream, yet the highest temperature recorded was only 160°. The chips too were blue from heat, showing that in spite of being covered with a stream of soluble oil not over 100° F. the metal cut must have reached at least 550° F., and thus the soluble oil was subjected to this high temperature locally as the chips were thrown through it. A rapid evaporation of the water in the soluble oil resulted from exposure to such intense heat, as was evident from a stream of steam-like vapor rising from it. It was similar, though very much smaller in volume, to the cloud of vapor rising from similar cuts in regular production while using mineral-lard oil. This indicates that most of the cooling effect of the cutting oil in these tests is probably due to its latent heat. It is thus interesting to recall that soluble oil has about five times as great a latent heat as lard or mineral oil, and over twice as great a specific heat.

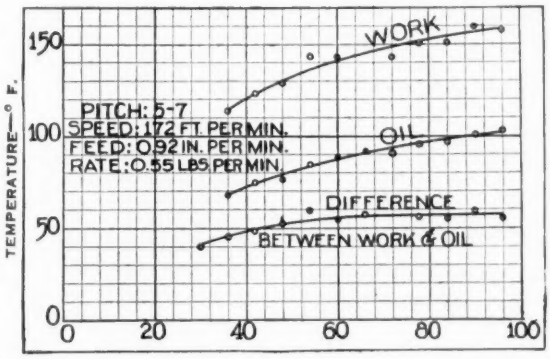


Fig. 13

Effect of High Production Rates on Hob Wear

The second series of tests was made to determine the effect of the *rate* of production, *i.e.*, the weight of metal removed per minute, and various combinations of speed and feed, on the wear of the hob per gear cut. The gears were of the same pitch as the first series, but with 33 teeth and 1¼" face. Comparative tests were made with a mixture of soluble oil with three parts of water, against the 40% mineral lard oil used in the shop. Any variation which could result from the varying hardness of different hobs, was eliminated by using the same hob for all tests in this series. After each test during which 25 gears were cut, the hob was sharpened until all signs of wear were removed, and then replaced in exactly the same position as during the previous test. The results shown in figure 14 are comparative only, because the wear shown is the average of the four teeth showing greatest wear rather than the maximum wear of any one tooth. The results are extraordinary, because of showing that the wear per gear cut decreases as the production rate is increased. Another interesting point is that tests with lard oil showed, if anything, more wear than for the soluble oil, though the tests were too few to be conclusive. It was shown also that for a given weight of metal removed per minute the wear was less at the lower r.p.m. of the hob, though the difference was really less than expected. The net power for cutting was found to vary directly with the rate of production, irrespective of the cutting speed, as shown in figure 15. The total power required, however, was higher for a given production rate at the higher r.p.m. on account of the increased bearing friction.

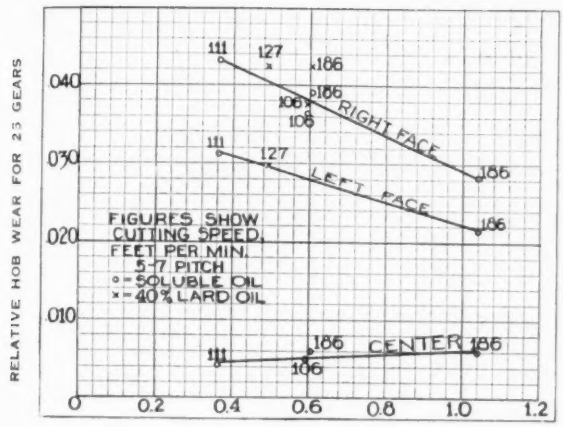


Fig. 14

Tests on Fellows Gear Shapers

A comparative and only qualitative test was made between soluble oil (1 part to 3 of water) and mineral lard oil on Fellows Gear Shapers while cutting the internal teeth of the pressed steel driving drums for disc clutches, shown in figure 5. There are 106 12-pitch teeth 3½ inches long, in each drum. Approximately 3.18 lbs. of metal was removed in cutting these teeth, about 75% of it being removed on the first complete cut around the drum and the remainder being taken as a finishing cut on the second cut around without changing the cutter.

The comparative test was made by cutting ten drums (a day's production) on each of two machines running side by side with the same operator and the same feeds and cutting speeds, one on each cutting oil. The machines were started with new cutters which were carefully examined by a microscope after the test. No material difference was found between the finished work of both machines in regard to accuracy, but there was a suggestion of a higher polish of the work from the machine where soluble oil had been used. Also the heating of the drums where they were being cut was noticeably less when using soluble oil, as was to be expected. This is of more than passing interest because the distortion caused by local heating during cutting influences the dimensions of the finished cut after the work has cooled.

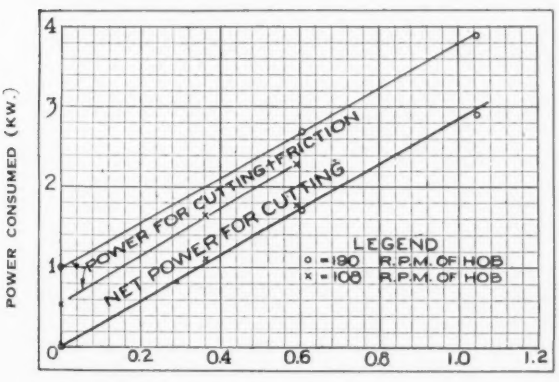


Fig. 15

The condition of the cutter after this test, is well shown by the micro photographs of the cutter shown in figure 16 which are to an enlargement of about 6½ diameters. "A" is the cutter used with mineral lard oil, and "B" the cutter used with soluble oil. The latter shows a good deal of lint between the teeth left from wiping with a soft cloth. Notice the dark band just below the cutting edges, resulting from the heat developed during cutting. Again, as was expected, the cutter using soluble oil shows less effect from heat.

An interesting fact revealed by these microphotographs which is hardly noticeable to the naked eye, is the clean worn edge about 0.004 inches wide on cutter "B". Very little sign of this phenomenon is found on cutter "A" but instead the edge is quite irregular due to lumps of metal scraped from the work being built up on the cutting edge. These irregular lumps are clearly shown in figure 17. They are soft and may be removed with a file, but they are firmly secured to the cutter. It is possible that they are a cause of scratches on the finished work, and hence explain the finer finish found when using soluble oil. It must not be inferred that these lumps do not occur when using soluble oil, but they are much fewer and smaller, as can be seen in at "B".

From the satisfactory results of this test, it was decided to speed up the machines and study the results. The maximum speed and feed possible with the belting in use was 170 strokes per minute (85 feet per minute) feed—200 strokes per inch pitch diameter—which was 70% above the normal rate. Three machines were run at this rate for a week, though previous experience with mineral lard oil had shown that the speeds already in use were as high as possible without frequent failure of the cutter before the completion of a day's run of ten drums. It was a surprise to find that the machines ran more smoothly at the higher

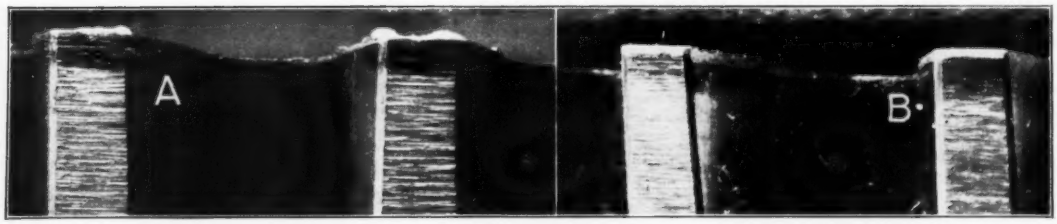


Fig. 16

A micro-photographic (x 6½) comparison of two teeth of a Fellows Cutter after use with lard oil (A) and after corresponding use with Soluble Oil (B).

speed. After cutting fifteen drums with soluble oil at 170% of normal rate, the cutters were removed and when examined were found to be in at least as good condition as is normally found after cutting only ten drums with lard oil.

It was thus concluded that with soluble oil a production at least 70% higher than the present standard is entirely feasible.

Conclusion

Short tests, such as these cannot be considered conclusive of course, but indicate very emphatically the desirability of such protracted tests as to determine if the unusually high production rates indicated by these tests as possible, are a money-saving proposition for normal production.

Almost all these experiments were made with soluble oil, the few runs made with lard oil showing no advantages whatever. This is particularly noteworthy since soluble oil is not usually looked on with favor for gear cutting, yet the machine operators like it because of its cleanly appearance and lack of the odor which is always present with hot lard oil. The work, too, does not get as hot and is therefor easier to remove from the machine without discomfort.

The indications that much higher production rates still are possible, as revealed by figure 14 are incentive enough to push similar experiments to a conclusion. It is expected that in many cases the most economical production rate will be so high that special attention will have to be given to lubricating bearings, for the lubrication of many cutting machines in use at present is very deficient to say the least. Cases are frequent where no oil is provided for bearings except that supplied when the operator squirts a few drops in an oil hole. These holes are sometimes in the wrong location, are plugged up or out of sight, and no provision is made to prevent the oil from running out as soon as added nor to keep adding a continual supply. These details while not serious for ordinary production rates make a great difference when speeding up a machine. Fortunately they are simple to correct when pointed out.

The experiments described here were made on gear cutting operations because they were thought to furnish a severe test for cutting oil. They will be followed by similar tests on a large variety of other operations in several manufacturer's plants which offer suitable conditions.

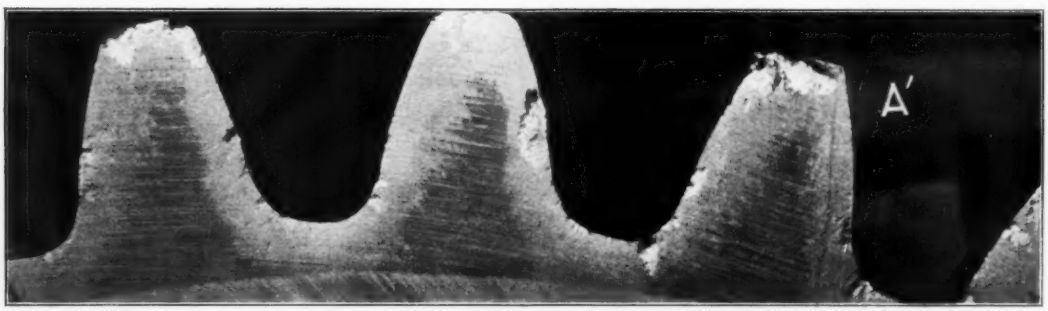


Fig. 17

A micro-photograph (x 6½) of the top of the teeth in Fig. 16-A showing lumps of metal built up on the cutting edges

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to the gear case

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You can well believe that these gears and pinions need the sturdiest kind of a lubricant.

On a large number of street railways, that need is met by Texaco Crater Compound.

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of a prominent manufacturer of machine tools

"Texaco Crater Compound is a highly adhesive, protective lubricant, which will withstand the severe pressures encountered in gear drives. It is not removed by exposure to moisture, heat or low temperature and provides protection under dust conditions. Texaco Crater Compound is a pure mineral lubricant and will not decompose or form a gum or other undesirable deposit. Its continued use on all gears is recommended in order to insure minimum wear."

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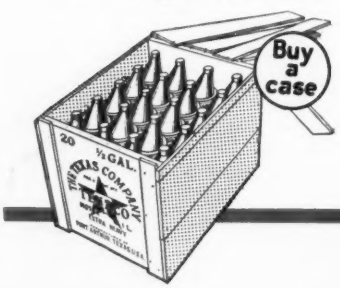
—in the right grade for your car

The Texaco Motor Lubrication Guide tells you what grade to use.

"and you can always have a can in the tool box, if you are forehanded enough to keep a case in the garage"

20 cans
in a strong wooden case